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NAVAL SURFACE WARFARE CENTER
Dahlgren, Virginia 22448-5100

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TORQUE STUDY ON MK 42 MOD 3 REAR FITTING SAFETY DEVICE SECTOR GEAR

BY SCOTT M. POMEROY
WEAPONS SYSTEMS DEPARTMENT

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Scott M. Pomeroy

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Naval Surface Warfare Center
Dahlgren Division (Code G34)
17320 Dahlgren Rd.
Dahlgren, VA 22448-5100

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13. ABSTRACT (*Maximum 200 words*)

This study analyzed the torque on the sector gear of the Mk 42 Mod 3 Rear Fitting Safety Device (RFSD) used in variable time (VT) fuzes for Navy gun ammunition. The study was initiated following two proposals by the production contractor to modify the sector gear to produce increased torque and improve its reliability when used in 5-in./38 caliber gun ammunition. The study concluded that one of the proposals was unsound and the other was feasible with a little fine tuning and further analysis.

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FOREWORD

The Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Dahlgren, Virginia, provides production support to the Naval Surface Warfare Center, Crane Division, Code PM4, as Design Agent (DA) for all Navy gun-fired projectile fuzes. Production support includes configuration management, documentation review, consultation with production contractors, analysis of laboratory and field tests, and resolution of problems and changes arising in fabrication.

This report documents a study performed in support of a production contract with Accudyne, Inc., of Janesville, Wisconsin to build MK 71 MOD 15 proximity fuzes. The study was initiated in response to a proposal by the contractor to increase the weight of the sector gear in the Mk 42 Mod 3 Rear Fitting Safety Device (RFSD). Past experiences have shown that substantial funding and schedule costs can be avoided by appropriate, judicious use of available projectile fuze analytic capabilities.

This report has been reviewed by Thomas N. Tschirn, Head, Guns and Munitions Division, and Don A. Wilson, Acting Fuze Branch.

Approved by:

David S. Malyevac

DAVID S. MALYEVAC
Deputy Department Head
Weapons Systems Department

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BACKGROUND

This study was performed by the Fuze Branch, Code G34, Naval Surface Warfare Center, Dahlgren Division (NSWCDD), Dahlgren, Virginia, in support of the procurement of Mk 71 Mod 15 variable time (VT) fuzes. These 5-in./38 fuzes were being built by Accudyne, Incorporated of Janesville, Wisconsin. The production contractor proposed a modification of the Mk 42 Mod 3 Rear Fitting Safety Device (RFSD) used in the Mk 71 fuze to provide safe separation of the round upon gun firing. The RFSD is also used in fuzes for 5-in./54 caliber and 76-mm/62 caliber ammunition.

The study was initiated following the contractor's proposal to improve reliability of the RFSD. The contractor theorized that the fuze failures experienced during lot acceptance tests were caused by inability of the sector gear assembly to generate enough torque to operate under the low 5-in./38 spin conditions. To generate more torque, two approaches were proposed for modification of the sector gear assembly. The first was the addition of a drop of solder, to the sector gear weight. This weight increase also changes the center of gravity of the sector gear assembly. The second was a change in the sector gear material from aluminum to brass to affect the same kind of change. The sector gear assembly, which consists of a gear, weight and camshaft, must rotate 118 degrees before the rotor can be released to arm the RFSD. Figure 1 is a drawing of the sector gear in its initial and final positions.

OBJECTIVE

The analysis was done to determine the torque on the existing sector gear and variations of the gear throughout its rotation. Torque is generated by centrifugal force caused by the spin of the projectile acting on the off-center weight in the sector gear.

APPROACH

The sector gear assembly was modeled and the torque data was tabulated using a combination of computer software programs. AutoCad, Version 10.0, was used to model the gear and also for direct measurements of the particular moment arms. ALGOR (finite element software, September 1991 version) was used to calculate the center of gravity of the complicated sector gear.

The torque generated by the sector gear assembly under centrifugal forces was calculated for the standard configuration sector gear and for the proposed changes using basic geometry equations. A data point was calculated for every degree of rotation of the sector gear (118 data points per plot). The spin rate used in the calculation for each of the guns was 200 revolutions per second (rps) for 5-in./38, 250 rps for 5-in./54, and 400 rps for 76-mm/62. The geometry

equations are shown in Figure 2. The center of gravity and initial position data is in Table 1.

RESULTS

Torque on the sector gear assembly varies during the gear's rotation and is also different for each gun system. Figure 3 shows the torque on the sector gear assembly as a function of degrees of rotation through its complete rotation for the 5-in./38, 5-in./54, and 76-mm guns. Figure 3 shows that, during the rotation of the sector gear, the torque starts low, peaks approximately halfway through its rotation and then drops. Figure 3 shows that the Mk 42 normally operates at a higher torque level in the 5-in./54 gun than the 5-in./38 gun and at a significantly higher level in the 76-mm gun. This figure was generated to compare the new proposed torque levels to the standards in existing guns. A helper spring is used to kick off the gear and assist the gear through its first 10 to 20 degrees of rotation. The added torque from the helper spring was not taken into account in this report. Typically, binding problems have occurred during the first quarter (after action of the helper spring is completed) or last quarter of rotation when torque is low.

Figure 4 shows the torque as a function of rotation after 0.035 grams (a drop) of solder was added to the sector gear's weight. The drop of solder in the cavity of the weight adds approximately 50 percent more torque during the initial stages of rotation and gradually drops down to 10 percent added torque near the end of rotation. This decrease in torque is due to the diminishing perpendicular moment arm from the center of the sector to the vector between the center of the RFSD and the sector's center of gravity. The standard 5-in./54 curve from Figure 3 was included in Figure 4 for comparison purposes. The increase in torque from the drop of solder was still not greater than the standard torque in the 5-in./54 gun.

Figure 5 shows torque values for a gear made of brass and indicates two potential problems. The negative torque in the initial stage of rotation shows that increasing the weight of the sector gear shifts the assembly's center of gravity closer to the center of rotation of the sector gear and crosses the vector connecting the RFSD's center and the sector's center of rotation. This creates a negative initial θ and causes centrifugal forces to drive the gear in the opposite (wrong) direction. The helper spring will likely overcome these forces in a properly running RFSD and the higher generated torque will drive the Safety and Arming (S&A) to arm faster. However, knowing the history of problems in this area, it is not wise to reduce torque at the startup in an effort to gain torque at the end of the rotation. The second potential problem is the higher torque at the end of rotation. This would not be a problem in a fuze for 5-in./38 ammunition, as seen in Figure 5 as the torque level remains below the torque generated in the 76-mm gun. If the brass sector gear was fired in the 76-mm gun, safety concerns exist with either early arming or a runaway caused by gear teeth failing under shear. The exact torque required to shear gear teeth was not taken into account in this report and therefore maximum acceptable torque was not taken into account.

CONCLUSIONS

On the surface, it appears that the approach of using a drop of solder on the weight could make the sector gear assembly more reliable in 5-in./38 ammunition by providing a little extra torque for the gear to drive through the forces attempting to bind it. However, further analysis and shock/spin testing would be necessary as the solder could pop out of the weight cavity during gun launch and interfere with the operation of the RFSD.

The material change proposal from aluminum to brass is not recommended because of the negative (counterclockwise) initial torque and the potential high torque gear teeth shearing problem that could arise if this design was ever used in the 76-mm gun.

The existing design was produced successfully in the past by both Eastman Kodak and Accudyne. Before these design proposals were suggested, Accudyne built RFSDs in accordance with the drawing package that passed the standard arming test. It was also proven by Kodak and Accudyne that sector gears in properly built RFSD's will completely arm in the lab at spin rates below 100 rps. This further proves that the torque level in the 5-in./38 is sufficient. The Navy has an interest in maintaining a single RFSD design which can be produced and safely used in 5-in. and 76-mm caliber guns. Modification of the sector gear assembly to improve the performance design margin for one caliber gun appears likely to produce safety concerns in another caliber.

RECOMMENDATIONS

No design changes were recommended at the time of the contract. A proposal to increase the size of the weight instead of adding drops of solder may be considered in the future; however, any increase to the sector gear assembly weight will require further dynamic analysis along with stress analysis and then shock and spin testing prior to approval of the proposed change.

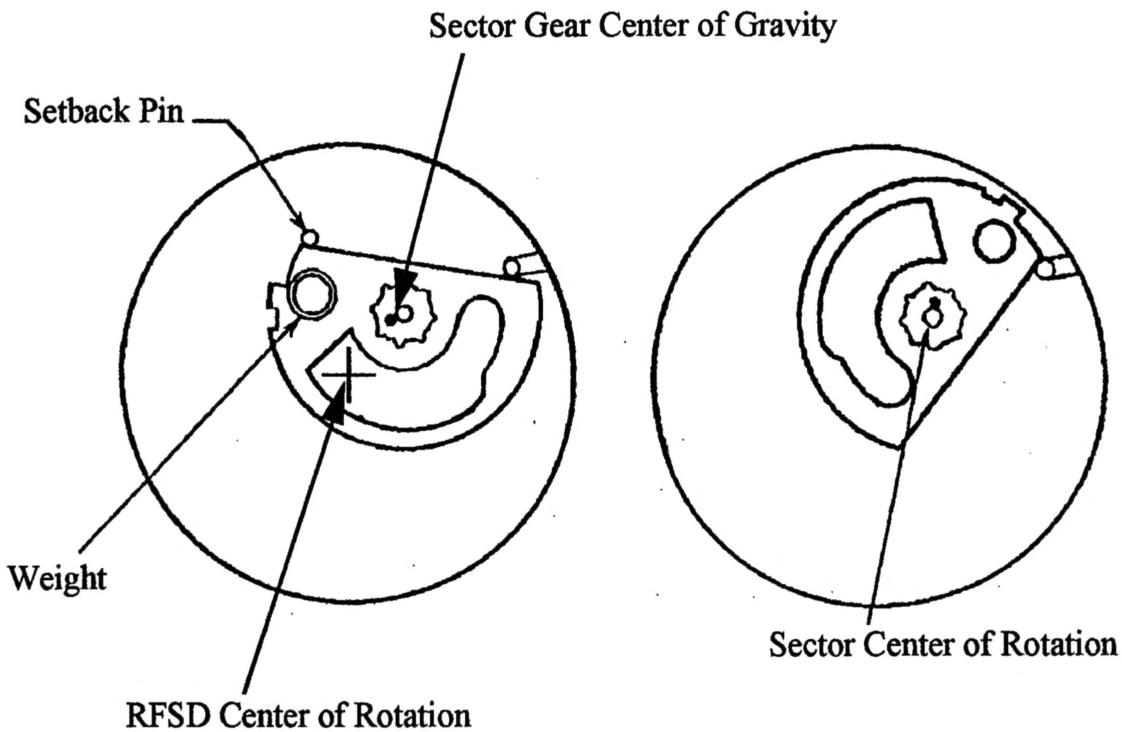
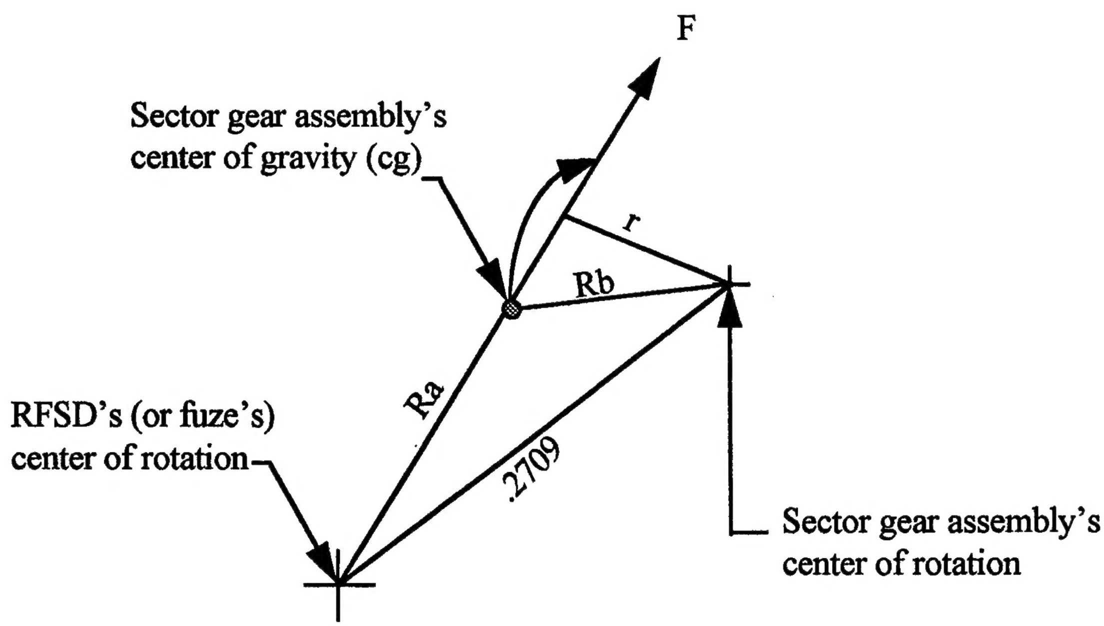


Figure 1. Sector Gear Initial (left) and Final (right) Positions



Equations:

R_b	=	radius from sector gear's rotational axis to the sector gear assembly's center of gravity. Varies as θ changes.
R_a	=	radius from fuze's rotational axis to the sector gear assembly's center of gravity. Varies as θ changes.
θ	=	varies from θ initial (θ_i) to $\theta_i + 118°$.
m	=	mass of sector gear assembly
ω	=	spin rate of the projectile
.2709	=	given distance between center of the fuze to sector gear's rotational axis
r	=	$R_b \sin(\pi-\beta)$ = radius perpindicular to force (F)
T	=	Fr = Torque
F	=	$\omega^2 m R_a$ = Force (centrepetal)
$\sin(\pi-\beta)$	=	$\sin(\beta) = (.2709/R_a)\sin\theta$, law of sines
k	=	conversion factor = $(2\pi \text{rad})^2/453.6$ grams x 386.4 in/s^2) = .000225
T	=	$\omega^2 m R_b (.2709)\, k \sin\theta$ (in-lb)

Figure 2. Sector Gear Geometry and Terminology

Table 1. Center of Gravity and Initial Position Data

A. Standard Sector Gear Assembly

Part	Center of Gravity Data			Initial Position Data		
	x_{cg}	y_{cg}	Weight (grams)	R_a (in)	R_b (in)	Initial θ (Degrees)
Sector Gear Weight Camshaft	0.356 0.0546 0.3666	-0.24 -0.15 -0.165	0.36 0.121 0.549			
Assembly	0.3262	-0.189	1.03	0.2289	0.0472	4.696

B. Drop of Solder in Weight

Part	Center of Gravity Data			Initial Position Data		
	x_{cg}	y_{cg}	Weight (grams)	R_a (in)	R_b (in)	Initial θ (Degrees)
Sector Gear Weight Camshaft	0.356 0.0546 0.3666	-0.24 -0.15 -0.165	0.36 0.156 0.549			
Assembly	0.3173	-0.188	1.065	0.2258	0.0545	30.723

C. Brass Sector Gear with Original Weight

Part	Center of Gravity Data			Initial Position Data		
	x_{cg}	y_{cg}	Weight (grams)	R_a (in)	R_b (in)	Initial θ (Degrees)
Sector Gear Weight Camshaft	0.356 0.0546 0.3666	-0.24 -0.15 -0.165	1.152 0.121 0.549			
Assembly	0.3392	-0.211	1.822	0.2171	0.0539	-3.902

Note:
To determine the center of gravity of the assembly (X_{cg}, Y_{cg}):

$$X_{cg} = \Sigma(WT \bullet x_{cg})/\Sigma(WT)$$

$$Y_{cg} = \Sigma(WT \bullet y_{cg})/\Sigma(WT)$$

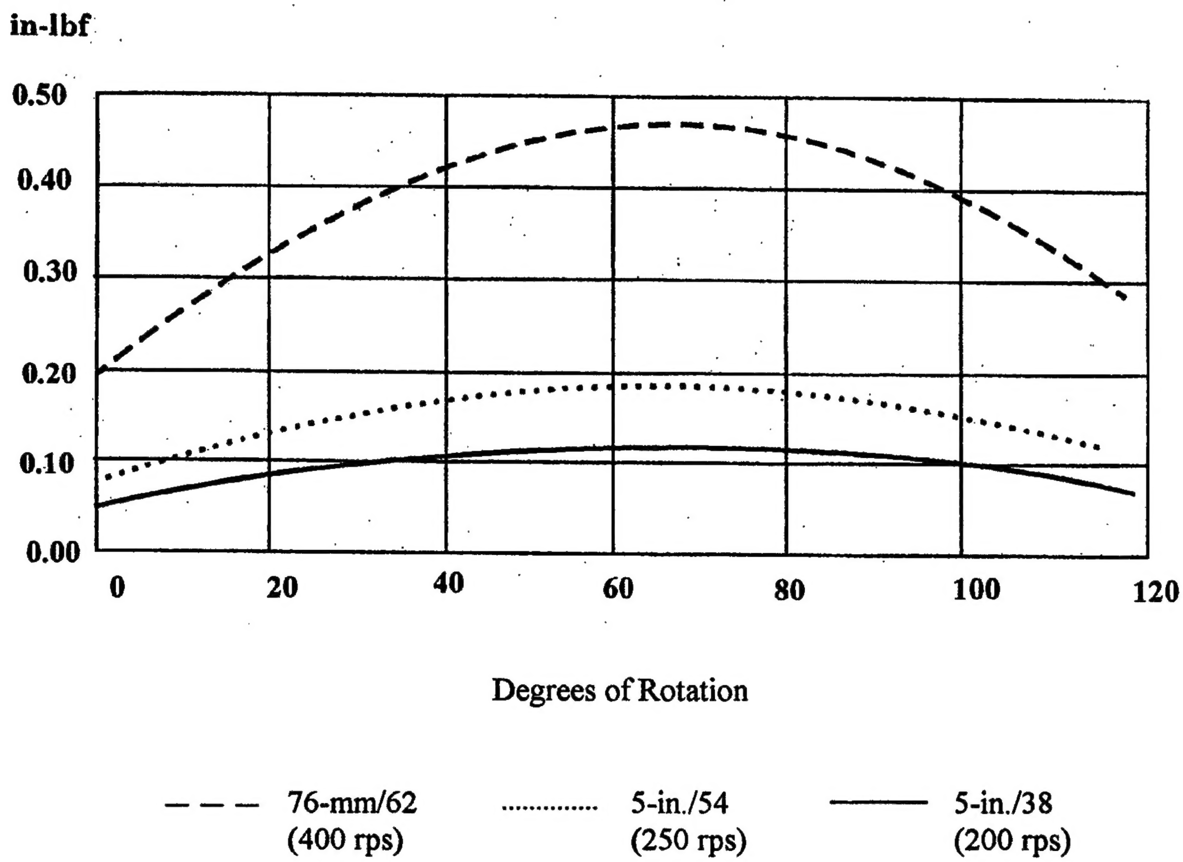


Figure 3. Torque on Sector Gear, Gun Comparison

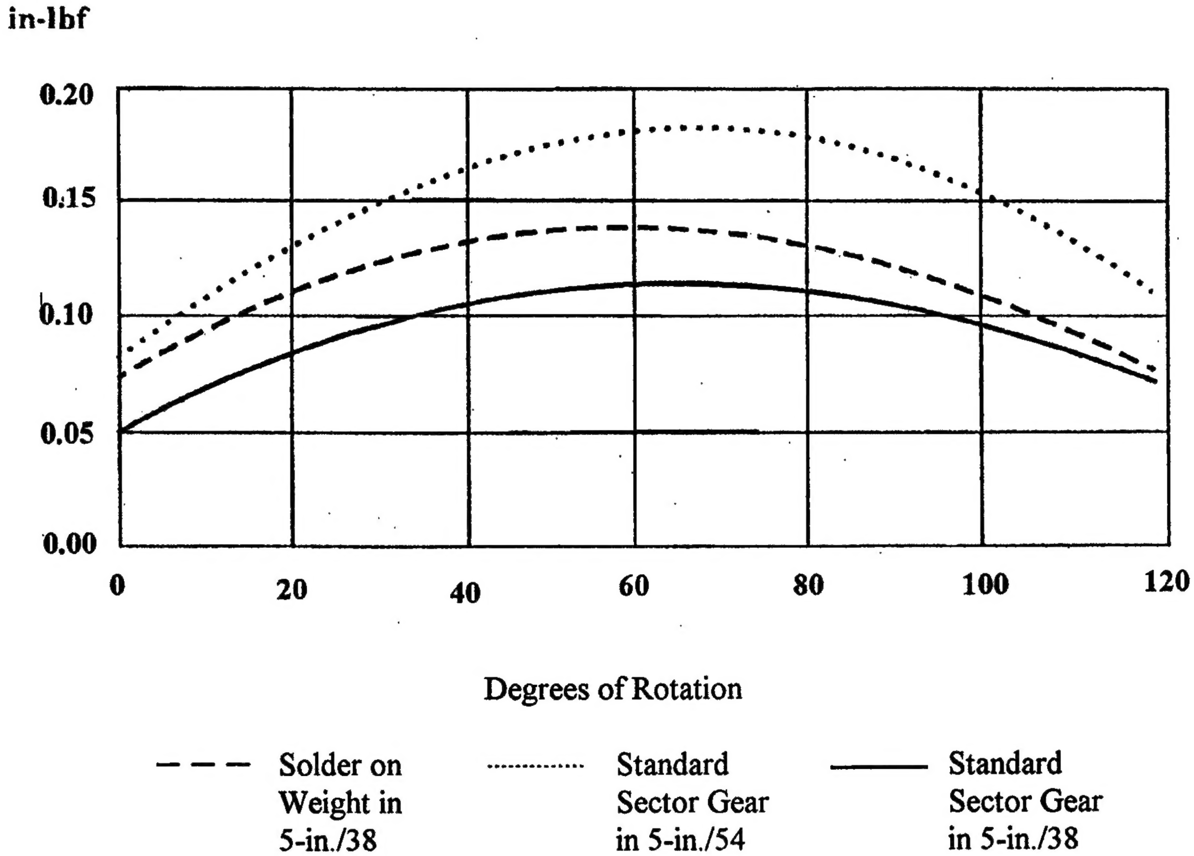


Figure 4. Torque on Sector Gear, Solder Weight Proposal

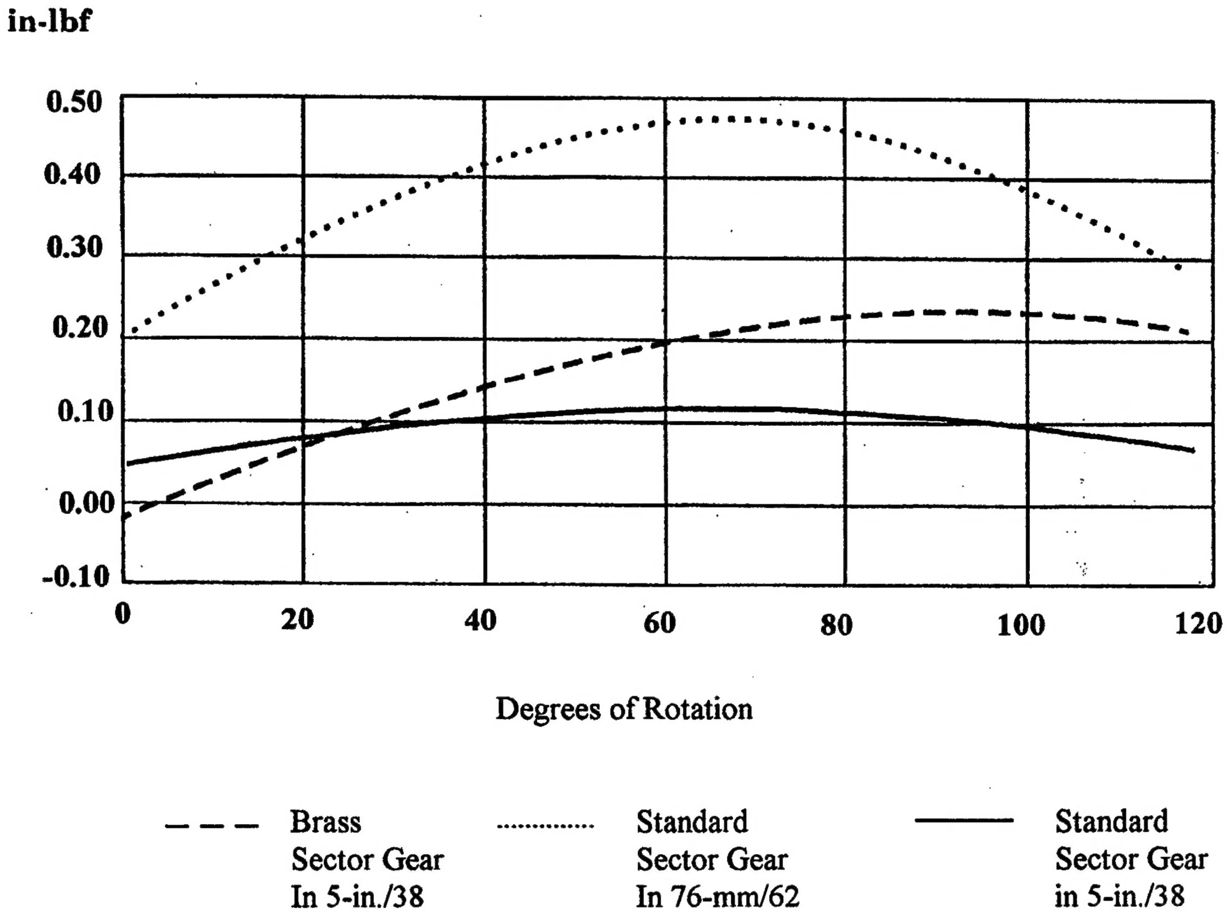


Figure 5. Torque on Sector Gear, Brass Sector Gear Proposal

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